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Admiral MANNERS, President, in the Chair.

The Rev. Joseph Spear, Chaplain, Bengal Establishment, Meerut,

was balloted for and duly elected a Fellow of the Society.

On the Comets 1857, *III. and V., and* 1867, *III.* By M. Hoek, Director of the Observatory of Utrecht. (Translation.)

In an addition to my Memoirs on Cometary Systems, see *Monthly Notices*, vol. xxvi. page 204, I have indicated the point of the sphere

IV. $\lambda = 75°{\cdot}5$ $\beta = -51°{\cdot}7$ .. Mean equinox of 1864·0,

as being probably a radiant point of cometary orbits.

I have therefore regarded as a remarkable circumstance, giving much interest to this point, its small distance from the point

$\lambda = 73°{\cdot}2$ $\beta = -51°{\cdot}6$ .. Mean equinox of 1864·0,

which was the point of intersection of the orbits obtained for the Comets 1857, III. and V.

I did not hesitate to attribute to these two bodies a common origin, considering the extreme resemblance of all the elements of their orbits, and the short interval between their appearance.

The Comet 1867, III. has just given an unexpected confirmation to this view. The circle which is the intersection of its orbit with the sphere passes through almost the same point of the sky.

The planes of the three orbits intersect therefore in the same line, which is necessarily parallel to the direction of the initial motion of the Comets.

Admitting for the orbits the following elements,

	Comet 1857, III.	1857, V.	1867, III.	
T	1857·54	1857·74	1867·85	
π	157° 52′	139° 54′	112° 58′	Mean equ. of 1864·0.
Ω	23 47	15 4	64 42	
i	121 3	123 57	96 14	
q	0·3675	0·5628	0·3333	
Calculator.	Villarceau.	Linsser.	Oppolzer.	

I find for the points of intersection

of the Orbits 1857, III. and 1857, V.	$\lambda = 73° 12'$	$\beta = -51° 36'$
,, 1857, III. and 1867, III.	72 32	− 51 19
,, 1857, V. and 1867, III.	72 33	− 51 23

of which the first is only half-a-degree distant from the two others.

These three Comets, then, have a common origin.

As to the aphelia they are situated at a considerable distance from the radiant point of the orbits. I find

For the Comet	Aphelion.		Distance of the Aphelion from the Radiant Point.
1857, III.	$\lambda = 51°·8$	$\beta = -38°·0$	20°·0
1857, V.	53·8	− 42·9	15·4
1867, III.	68·5	− 31·5	20·1

but, what is remarkable, all the aphelia are on the same side as regards the radiant point. In following the orbits in the direction of the retrograde motion, we meet the radiant point before we arrive at the aphelia. The last ten years have thus furnished us with two cometary systems, each composed of three members; first, that of the years 1860 and 1863, then that of the years 1857 and 1867.

It appears that it would be to mistake the principles of the theory of probabilities, if we attributed all these coincidences to mere chance.

Since I have been occupied with these researches, the calculations of M. Schiaparelli on the current of meteors coming from the stellar spaces have strongly corroborated my conclusions. This Astronomer has succeeded in showing the intimate con-

nexion which there is between comets and falling stars; an important discovery, and known now to all the world. Naturally it has suggested the idea of seeking, if I could not find, a connexion between cometary systems and falling stars. In a subsequent Memoir I shall occupy myself with the theory which ought to serve as a guide in this investigation.

On the Phenomena which a very extended Swarm of Meteors coming from Space presents after its entry into the Solar System. By M. Hoek, Director of the Observatory of Utrecht. (Translation.)

I propose to examine in this Memoir the phenomena which will be presented by a swarm of corpuscules coming to us from the stellar spaces, and which is sufficiently extended to embrace the whole terrestrial orbit, that is, to give us a continuous rain of meteors during an entire year.

I shall determine the orbit of each molecule, the density of the swarm in the neighbourhood of the terrestrial orbit, the variations in the position of the radiant point, and lastly, the perturbations produced by the attraction of the Earth. But as we are only concerned with a first approximation, I shall admit that these corpuscules do not exercise any mutual influence, and that consequently their initial motions are parallel, and further that the initial velocity common to all the particles is that given by parabolic orbits round the Sun. Lastly, I shall neglect the ellipticity of the orbit of the Earth, and I shall consider this planet as a body composed of homogeneous and concentric spherical layers.

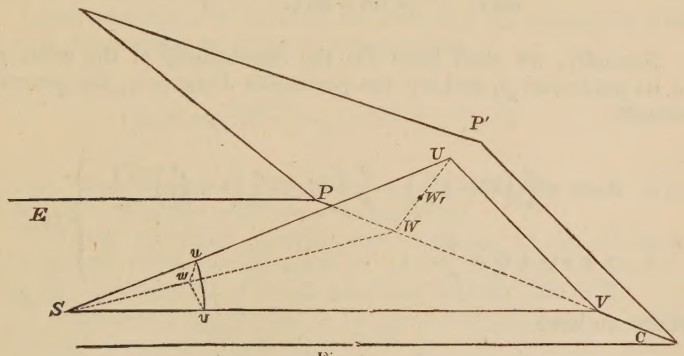


Fig. 1.

§ 1. Let E C (fig. 1) be the plane of the ecliptic, S the Sun, S U a line parallel to the initial motion of the swarm, motion

with which each molecule enters into the sphere of activity of the Sun.

Let us write $SU = A$, and determine the direction of this line by the longitude L and the latitude B of the point U; and, to fix the ideas, let this latitude be taken to be northern.

Let PP′ be a plane normal to the line SU, cutting the ecliptic in PC. Lastly, let SUV be a third plane normal to the two others and containing the line SU. We have $USV = B$.

Suppose now that a corpuscule passes through any point whatever W situate in the plane PP′ and determined by the co-ordinates $VUW_1, = \zeta$, $UW_1, = s$. The orbit of the meteor round the Sun will be included in the plane USW, the position of which is easily determined. For this purpose let us represent to ourselves about the Sun as centre a sphere radius unity, and we shall have a spherical triangle uvw, the elements of which will be

$$uv = B, \quad uw = n, \quad vw = h, \quad uvw = 90°, \quad vuw = \zeta,$$

whence

$$\left.\begin{aligned} \tan h &= \tan \zeta \sin B, \\ \tan B &= \tan n \cos \zeta, \\ \cos n &= \cos B \cos h, \end{aligned}\right\} \quad (1)$$

or if we prefer to introduce the descending node and the inclination of the orbit, that is to say, if we write $h = \mathfrak{S} - L$, and the angle $uwv = i$, then

$$\left.\begin{aligned} \tan(\mathfrak{S} - L) &= \tan \zeta \sin B, \\ \tan i &= \frac{\tan B}{\sin(\mathfrak{S} - L)}, \\ \cos i &= \cos B \sin \zeta. \end{aligned}\right\} \quad (2)$$

Secondly, we shall have for the excentricity of the orbit e, for its parameter p, and for the perihelion distance q, the general formulæ

$$\left.\begin{aligned} e^2 - 1 &= \frac{c^2}{\mu^2}\left(V^2 - 2\frac{\mu}{R}\right) = \frac{c^2}{\mu^2}\left[V^2 - 2\frac{\mu}{A}\left(1 + \frac{s^2}{A^2}\right)^{-\frac{1}{2}}\right], \\ p &= q(1+e) = \frac{c^2}{\mu}, \end{aligned}\right\} \quad (3)$$

where we have

V, the initial velocity,

μ, the constant of solar attraction (the k^2 of Gauss),

$\frac{1}{2}c$, the area described by the radius vector in the unity of time ($c = Vs$),

R, the initial distance $SW_1, = \sqrt{A^2 + s^2}$.

Let us now admit that for the corpuscule passing through U, that is, for which $s = 0$, the velocity is that in a parabola, consequently $e = 0$, and the formula (3) will give

$$V^2 = 2\frac{\mu}{A}, \tag{4}$$

In this case all the other corpuscules will describe hyperbolas, but we may say that all these orbits will not sensibly differ from parabolas, so long as we only occupy ourselves with the meteors which meet the orbit of the Earth. In fact, this restriction gives $q \leq 1$, and since from the formulæ (3) and (4)

$$e - 1 = q\frac{2}{A}\left(\frac{1}{2}\frac{s^2}{A^2} - \frac{3}{8}\frac{s^4}{A^4} + ..\right) = \frac{q}{A}\frac{s^2}{A^2}\left(1 - \frac{3}{4}\frac{s^2}{A^2} + ..\right), \tag{5}$$

the excess of e above unity is a very small quantity. In order to calculate it, we then have with a close approximation, from (3) and (4),

$$2q = \frac{V^2 s^2}{\mu} = 2\frac{s^2}{A}, \tag{6}$$

which gives for the formula (5)

$$e - 1 = \left(\frac{q}{A}\right)^2\left(1 - \frac{3}{4}\frac{q}{A} + ..\right), \tag{7}$$

that is to say, that for $q = 1$, $A = 10000$, the excentricity will not sensibly differ from unity, and consequently q will not sensibly differ from the value given by the formula (6).

Lastly, the angle M between the axis and the asymptote will be very approximately given by the equation,

$$\tan M = \sqrt{e^2 - 1} = \sqrt{2(e - 1)} = \frac{q}{A}\sqrt{2}. \tag{8}$$

so that, according to the foregoing suppositions, we shall have $M = 29''$, a quantity which may be neglected.

We shall therefore consider each molecule as describing a parabola the perihelion distance of which is given by the formula (6), and the axis of which coincides with the line S U.

It remains to inquire what is the geometric locus in the plane P P′ of all the points W_1 through which pass the molecules which afterwards meet the terrestrial orbit.

We have for the orbit of each molecule

$$r(1 + \cos v) = 2\frac{s^2}{A}, \tag{9}$$

or introducing the relations $r = 1$, $v = 180° + n$, this becomes

$$1 - \cos n = 1 - \cos h \cos B = 2\frac{s^2}{A}, \qquad (10)$$

whence from the formulæ (10) and (1)

$$\cos^2 n\,(1 + \tan^2 n) = 1 = \left(2\frac{s^2}{A} - 1\right)^2 \left(1 + \frac{\tan^2 B}{\cos^2 \zeta}\right), \qquad (11)$$

the equation of the required curve in the polar co-ordinates s and ζ. To obtain it in rectangular co-ordinates, we may write $s^2 = x^2 + y^2$ and $\frac{1}{\cos \zeta} = \frac{s}{x}$, so that the line U V has in fact been chosen for the axis of x. This gives

$$4x^4 + 4x^2y^2(1 + \sin^2 B) + 4y^4 \sin^2 B - 4Ax^2 - 4Ay^2 \sin^2 B + A^2 \sin^2 B = 0$$

a curve which is symmetric in regard to each axis.

For $y = 0$ the equation gives

$$x_1 = \pm\sqrt{\tfrac{1}{2}A(1 + \cos B)}, \quad x_2 = \mp\sqrt{A(1 - \cos B)},$$

where the upper signs belong to the corpuscules which, as they cut the orbit of the Earth, are in their descending node; the lower signs to those which only cut the Earth's orbit after they have gone round the Sun and arrived at the ascending node.

For $x = 0$, the equation gives $y = \pm\sqrt{\frac{1}{2}A}$,

„ $B = 90°$ „ $x^2 + y^2 = \frac{1}{2}A$,

„ $B = 0$ „ $x^2 = 0$ and $x^2 + y^2 = A$.

that is to say, the line P C, and a circle having its centre on this line. In the latter case $q = 1$, and from the formula (10), $\cos h = -1$, which are co-ordinates of the perihelion common to all the orbits which pass through any point of the circle.

§ 2. What is the density of the swarm at any point of the Earth's orbit, taking for unity the density in the neighbourhood of the plane P P′?

To answer this question let us follow the motions of the eight molecules, the initial positions of which at the same instant were expressed by the co-ordinates,

No. 1.	by	$(s,$	$\zeta,$	$A),$
2.	,,	$(s,$	$\zeta + d\zeta,$	$A),$
3.	,,	$(s + ds,$	$\zeta,$	$A),$
4.	,,	$(s + ds,$	$\zeta + d\zeta,$	$A),$
5.	,,	$(s,$	$\zeta,$	$A + dA),$
6.	,,	$(s,$	$\zeta + d\zeta,$	$A + dA),$
7.	,,	$(s + ds,$	$\zeta,$	$A + dA),$
8.	,,	$(s + ds,$	$\zeta + d\zeta,$	$A + dA).$

Originally they formed a rectangular parallelopiped of the volume $ds \times s\,d\zeta \times dA$. We have to find the volume comprised between the positions when they have arrived near the terrestrial orbit.

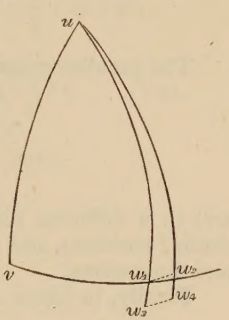


Fig. 2.

Everything being symmetrical about the line S U, it at once appears that Nos. 1 and 2 will arrive at the same instant at the points w_1 and w_2 of the sphere radius unity described about the Sun, and that $u w_1 = u w_2$ (fig. 2), Nos. 3 and 4 will arrive a little later at w_3 and w_4; Nos. 5 to 8 will follow the others at a distance sensibly constant for all these numbers.

The calculation may be conducted in two manners.

I. We may consider first what happens in the plane $u w_1 w_3$, and multiply by $w_1 w_2$ the area of the parallelogram formed by the Nos. 1, 3, 5, and 7 (fig. 3). At the moment that No. 1 arrives

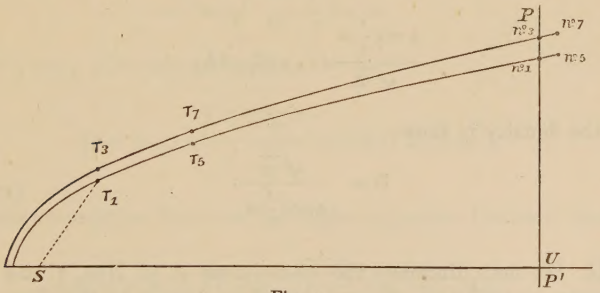


Fig. 3.

at τ_1 at the distance 1 from the Sun, the others will be at τ_3, τ_5 and τ_7.

The primitive velocity being $\sqrt{\frac{2\mu}{A}}$, that at the distance 1 $= \sqrt{2\mu}$, we have

$$dA = \sqrt{\frac{2\mu}{A}}\,dt, \qquad \tau_1\tau_5 = \sqrt{2\mu}\,dt = \sqrt{A}\,dA. \qquad (13)$$

The equation $y^2 = p^2 + 2px$ of the parabola $\tau_1\tau_5$ for the origin S then gives for the distance of the two neighbouring parabolas measured in a direction parallel to the axis of y,

$$dy = \frac{p+x}{g}\,dp = \frac{r}{y}\,dp,$$

whence writing $r = 1$, $y = \sin n$, for the distance of the two parabolas $\tau_1\tau_5$ and $\tau_3\tau_7$, we have

$$dy \cos\frac{1}{2}n = \frac{dp}{2\sin\frac{1}{2}n} = \frac{dy}{\sin\frac{1}{2}n} = \frac{2s\,ds}{A\sin\frac{1}{2}n}. \qquad (14)$$

The parallelogram $\tau_1\tau_3\tau_7\tau_5$, has, therefore, a surface

$$\tau_1\tau_5 \times dy\cos\frac{1}{2}n = \frac{2s\,ds\,dA}{\sin\frac{1}{2}n\sqrt{A}}, \qquad (15)$$

and in a different plane the Nos. 2, 4, 6, 8, will have perfectly similar positions, and will form a parallelogram of the same shape and dimensions.

Finally, in figure 2,

$$w_1w_2 = w_3w_4 = \sin n\,d\zeta, \qquad (16)$$

whence the volume comprised between the eight molecules when they arrive at the terrestrial orbit is

$$\frac{4\cos\frac{1}{2}n}{\sqrt{A}}ds\,.\,s\,d\zeta\,.\,dA,$$

and the density is thus

$$D = \frac{\sqrt{A}}{4\cos\frac{1}{2}n}. \qquad (17)$$

II. We may diminish the co-ordinate A of Nos. 3 and 4 by a certain quantity so chosen that they arrive at the distance 1 from the Sun simultaneously with Nos. 1 and 2. Doing the same thing for the co-ordinate $A + dA$ of Nos. 7 and 8, the primitive parallelopiped will have changed its form, preserving a constant volume.

In this case Nos. 5 to 8 will be at a distance $1 + dr$ from the Sun at the instant when Nos. 1 to 4 have reached the sphere radius 1. We have, therefore, to multiply the surface $w_1w_2w_3w_4$, by dr.

We have already

$$w_1 w_2 = \sin n \, d\zeta, \tag{16}$$

and, differentiating the formula (10),

$$w_1 w_3 = d n = \frac{4 s \, d s}{\mathrm{A} \sin n}. \tag{18}$$

It remains to find $d r$. The general formulæ

$$r^2 d v = \sqrt{p \mu} \, d t,$$

$$r = \frac{p}{1 + e \cos v}, \text{ with its differential } \quad d r = \frac{r^2}{p} e \sin v \, d v,$$

give

$$r \, d r = \sqrt{(e^2 - 1) r^2 + 2 p r - p^2} \sqrt{\frac{\mu}{p}} \, d t. \tag{19}$$

Hence, in our case where $e = 1$, $p = 2 q$, we have

$$r \, d r = \sqrt{r - q} \, \sqrt{2 \mu} \, d t.$$

and, considering $d t$ as a constant quantity,

$$r \, d r = \sqrt{\frac{r - q}{\mathrm{R} - q}} \, \mathrm{R} \, d \mathrm{R}, \tag{20}$$

a formula which for $\mathrm{R} = 1$, $\mathrm{R} \, d \mathrm{R} = \mathrm{A} \, d \mathrm{A}$, gives

$$d r = \sqrt{\frac{1 - q}{\mathrm{R} - q}} \, \mathrm{A} \, d \mathrm{A},$$

or with a very close approximation

$$d r = \mathrm{A} \, d \mathrm{A} \sqrt{\frac{1 - q}{\mathrm{A} - \frac{1}{2} q}} = \sqrt{\mathrm{A} (1 - q)} \, d \mathrm{A},$$

the volume comprised between the eight molecules becomes therefore

$$w_1 w_2 \times w_1 w_3 \times d r = 4 \sqrt{\frac{1 - q}{\mathrm{A}}} \, d s \, . \, s \, d \zeta \, . \, d \mathrm{A},$$

and the required density, as before

$$\mathrm{D} = \frac{1}{4} \sqrt{\frac{\mathrm{A}}{1 - q}} = \frac{\sqrt{\mathrm{A}}}{4 \cos \frac{1}{2} n}.$$

It is to be remarked that D is the real density. The apparent density, or number of meteors which fall during a certain time,

will depend not only on D, but also on their relative velocity in regard to the Earth, and on the perturbations which this planet produces in their movements.

The following table, calculated from the formulæ (1) and (17) for $B = 51^\circ\ 30'$ and for successive values of h, gives an *aperçu* of the densities of different parts of the same swarm at the moment when they meet the orbit of the Earth. The density is taken to be 1 for $A = 10000$.

h	n	D
± 0°	51° 30′	27° 7′
± 15	53 3	27 9
± 30	57 23	28 5
± 45	63 53	29 5
± 60	71 52	30 9
± 75	80 44	32 8
± 90	90 0	35 3
± 105	99 16	38 6
± 120	108 8	42 6
± 135	116 7	47 2
± 150	122 37	52 2
± 175	126 57	56 0
± 180	128 30	57 5

§ 3. What is the radiant point which the swarm will present at any point of the Earth's orbit ?

It appears, in the first place, that at every instant there exist two of these points, one of them for the meteors which are at their descending node, the other for those which, having attained their ascending node, have the same velocity but in a directly contrary direction. The two may be calculated successively.

For this purpose it is to be remembered that every tangent to a parabola divides into two equal parts the angle formed by the radius vector and the diameter produced.

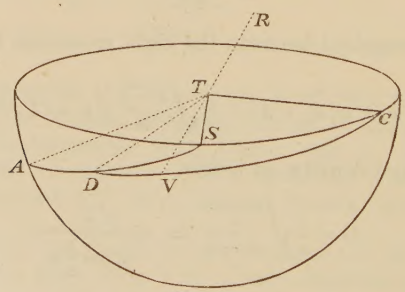


Fig. 4.

Suppose, then, fig. 4, that T is the Earth, occupying the

centre of a sphere whereon A denotes the point opposite to V; that is to say, that T A is taken in space parallel to the line S U. Let S be the Sun, D a point dividing the arc A S into two equal parts; the meteor, as it meets the Earth, will have the direction T D, and, we may add, the velocity $\sqrt{2\mu}$. Hence, taking the arc S C = 90°, T C will be the direction of the motion of the Earth taken in the inverse sense. Whence it follows that a parallelogram constructed on the lines T C and T D with the lengths $\sqrt{\mu}$ and $\sqrt{2\mu}$ will give, by its diagonal, the relative motion of the meteors in direction and magnitude. This diagonal, situate in the plane D T C, will cut the sphere somewhere in V. Thus the point V will be opposite to the radiant point R.

For the calculation, we shall unite the points A, D, S, C, and V with the north pole P, and express their position in longitude and polar distance.

Taking l for the longitude of the Earth, seen from the Sun, we shall have

For A	longitude	$180° + L$	Polar Dist.	$= P = 90° + B$
,, S	,,	$180 + l$		$= 90°$
,, C	,,	$270 + l$		$= 90$
,, D	,,	$180 + L + \lambda_1$		$= \varpi_1$
,, V	,,	$180 + L + \lambda_2$		$= \varpi_2$
,, R	,,	$l + \lambda_2$		$= 180 - \varpi_2$

we write moreover D C = H, D V = α, and A S = n = arc $u w$ of figure 1.

In order to facilitate the calculation, let us represent a spherical triangle M N O (fig. 5), divided into two parts by an arc of great circle N P. Let $\Phi + \Psi = N$, $\varphi + \psi = n$, $m = 90°$, we shall have, equating the values of sin O and of cos O derived successively from the triangles N O P and N O M,

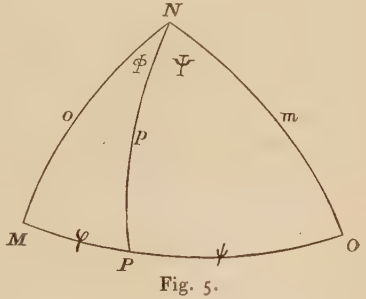


Fig. 5.

$$\sin p = \sin o \frac{\sin \psi}{\sin \Psi} \frac{\sin N}{\sin n}, \quad \cos p = \cos o \frac{\sin \psi}{\sin N}, \quad (22) \text{ and } (23)$$

$$\tan p = \tan o \frac{\sin N}{\sin \Psi}, \quad (24)$$

$$\sin p \sin \Psi = \sin o \sin \psi \frac{\sin N}{\sin n}, \quad \sin p \cos \Psi = \cos \psi, \quad (22) \text{ and } (25)$$

$$\tan \Psi = \tan \psi \sin o \frac{\sin N}{\sin n}, \qquad (26)$$

$$\cos n = \sin o \cos N. \qquad (27)$$

Applying to the triangle A P S the formulæ (22), (24), (26), 27), we have

$$n = n,\ \phi = \psi = \frac{1}{2} n,\ o = P,\ p = \pi_1,\ N = l - L,\ \Psi = l - L - \lambda_1,$$

whence

$$\sin \pi_1 = \frac{\sin P \sin (l - L)}{2 \cos \frac{1}{2} n \sin (l - L - \lambda_1)},\ \tan \pi_1 = \tan P \frac{\sin (l - L)}{\sin (l - L - \lambda_1)},$$

(28) and (29)

$$\tan (l - L - \lambda_1) = \frac{\sin P \sin (l - L)}{2 \cos^2 \frac{1}{2} n},\ \cos n = \sin P \cos (l - L).$$

(30) and (31)

Applying next to the triangle D P C the formulæ (24), (26), and (27), we have

$$n = H,\ \phi = \alpha,\ \psi = H - \alpha,\ o = \pi_1,\ p = \pi_2,\ N = 90° + l - L - \lambda_1,\ \psi = 90° - \lambda_2,$$

whence

$$\tan \pi_2 = \tan \pi_1 \frac{\cos (l - L - \lambda_1)}{\cos \lambda_2},\ \cot \lambda_2 = \frac{\tan (H - \alpha)}{\sin H} \sin \pi_1 \cos (l - L - \lambda_1),$$

(32) and (33)

$$\cos H = - \sin \pi_1 \sin (l - L - \lambda_1). \qquad (34)$$

The formulæ (28), (30), and (33), give

$$\tan \lambda_2 = \frac{\sin H \cot (H - \alpha)}{\cos \frac{1}{2} n}, \qquad (35)$$

the formulæ (29), (30), and (32),

$$\tan \pi_2 = \frac{2 \cos^2 \frac{1}{2} n}{\cos P \cos \lambda_2}, \qquad (36)$$

the formulæ (28) and (34),

$$\cos H = - \frac{\sin P \sin (l - L)}{2 \cos \frac{1}{2} n}, \qquad (37)$$

and the problem will thus be resolved as soon as we know the value of cot (H − α) To calculate it, we have in a rectilinear triangle, the half of the parallelogram of the motions,

Angles α, $H - \alpha$, and $180° - H$.

Corresponding sides $\sqrt{\mu}$, $\sqrt{2\mu}$, and $\sqrt{(3 + 2\sqrt{2}\cos H)\mu}$,

whence

$$\frac{\sin^2 H}{\sin^2 (H - \alpha)} = \frac{3 + 2\sqrt{2}\cos H}{2}, \quad \cos^2 (H - \alpha) = \frac{(1 + \sqrt{2}\cos H)^2}{3 + 2\sqrt{2}\cos H},$$

$$\sin H \cot (H - \alpha) = \frac{1 + \sqrt{2}\cos H}{\sqrt{2}} = \cos 45° + \cos H. \qquad (38)$$

To resume, the system of formulæ necessary for the calculation is

$$\left.\begin{aligned} &\cos n = \sin P \cos (l - L), \\ &2 \cos \tfrac{1}{2} n \cos H = -\sin P \sin (l - L), \\ &\tan \lambda_2 = \frac{\cos 45° + \cos H}{\cos \frac{1}{2} n}, \quad \tan \pi_2 = \frac{2 \cos^2 \frac{1}{2} n}{\cos P \cos \lambda_2}, \\ &\text{longitude of R} = l + \lambda_2, \\ &\text{N. latitude of R} = \pi_2 - 90°, \end{aligned}\right\} \qquad (39)$$

In the second place, we have to occupy ourselves with the second radiant point belonging to the meteors which are at the

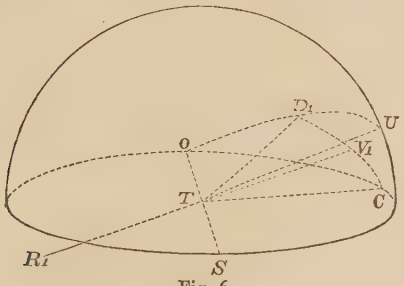


Fig. 6.

ascending node. In this case, taking (fig. 6) U for the point

opposite to A, and O for that opposite to S, let D_1 be the point situate at the middle of the arc UO, and V_1 the point marked on the sphere by the diagonal of the parallelogram constructed on the lines TD_1 and TC. We have for

for U,	longitude	$= L$	polar distance		$= 180° - P$
,, O	,,	$= l$	,,	,,	90
,, C	,,	$= l - 90°$	,,	,,	90
,, D_1	,,	$= L + \lambda_1$	,,	,,	π_1
,, V_1	,,	$= l - \lambda_2$	,,	,,	π_2
,, R_1	,,	$= 180° + l - \lambda_2$	,,	,,	$180 - \pi_2$

and then

$$D_1C = H, \quad D_1V_1 = \alpha, \quad OU = n,$$

and the repetition of the calculation gives

$$\left.\begin{aligned} \cos n &= \sin P \cos (l - L), \\ 2 \cos \tfrac{1}{2} \cos H &= \sin P \sin (l - L), \\ \tan \lambda_2 = \frac{\cos 45° + \cos H}{\cos \tfrac{1}{2} n}, &\quad \tan \pi_2 = -\frac{2 \cos^2 \tfrac{1}{2} n}{\cos P \cos \lambda_2}, \\ \text{Longitude of } R_1 &= 180° + l - \lambda_2, \\ \text{N. latitude of } R_1 &= \pi_2 - 90°. \end{aligned}\right\} \quad (40)$$

Hence, introducing the longitude of the Sun $= \odot$, the latitude of the point $U = B_1$, that of the point $R = \beta_2$, and uniting the formulæ for the two cases, we have

$$\left.\begin{aligned} \cos n &= -\cos B \cos (\odot - L), \\ \cos H &= \frac{\cos B \sin (\odot - L)}{2 \cos \tfrac{1}{2} n}, \\ \tan \lambda_2 = \frac{\cos 45° \pm \cos H}{\cos \tfrac{1}{2} n}, &\quad \tan \beta_2 = \pm \frac{\sin B \cos \lambda_2}{2 \cos^2 \tfrac{1}{2} n}, \\ \text{Long. of } R &= 180° + \odot + \lambda_2 = \odot - \lambda_2, \\ \text{N. lat. of } R &= \beta_2, \end{aligned}\right\} \quad (41)$$

where the upper signs belong to the meteors at the descending node, the lower ones to those at the ascending node.

The knowledge of the relative motion is a great step in advance towards finding the apparent density of the rain of meteors.

This will be proportional to

$$D\sqrt{(3+2\sqrt{2}\cos H)\,\mu} = \frac{\sqrt{A\mu}}{4\cos\frac{1}{2}n}\sqrt{3\pm\frac{1.4\cos\beta\sin(\odot-L)}{\cos\frac{1}{2}n}} \quad (42)$$

on the supposition that the attraction of the Earth has no influence on the motion of the corpuscules. But this action being sometimes very sensible, it follows that the formula (42) gives only a first approximation to the apparent density.

The following table, calculated from the formula (41), where U is taken to be the radiant point of the Comets of 1857 and 1867, will show how considerable are the annual variations of the radiant points. With $L = 72^\circ\,45'$, $B = -51^\circ\,30'$, I find

Date.	⊙	*n*.	H.	The Point R. Long.	The Point R. Lat.	The Point R_1. Long.	The Point R_1. Lat.
	°	° ′	° ′	° ′	° ′	° ′	° ′
Dec. 4	252 45	51 30	90 0	110 53	−20 46	214 37	+20 46
Jan. 3	282 45	57 23	100 13	133 53	−23 32	237 31	+19 42
Feb. 2	312 45	71 52	109 26	157 33	−28 26	260 40	+20 8
Mar. 3	342 45	90 0	116 7	183 26	−36 13	284 24	+22 1
Apr. 2	12 45	108 8	117 20	215 39	−46 19	309 27	+27 3
May 3	42 45	122 37	108 55	261 20	−53 0	337 43	+35 36
June 3	72 45	128 30	90 0	311 11	−47 21	14 19	+47 21
July 4	102 45	122 37	71 5	347 47	−35 36	64 10	+53 0
Aug. 5	132 45	108 8	62 40	16 3	−27 3	109 51	+46 19
Sept. 4	162 45	90 0	63 53	41 6	−22 19	142 4	+36 13
Oct. 5	192 45	71 52	70 34	64 50	−20 8	168 57	+28 26
Nov. 4	222 45	57 23	79 47	87 59	−19 42	191 37	+23 32

§ 4. In the last place, we proceed to calculate the influence of the attraction of the Earth on the density of the rain of meteors, and on the position of the radiant point.

The relative velocity $\sqrt{(3+2\sqrt{2}\cos H)\,\mu}$ has a minimum for $H = 180^\circ$, and the value is then $= 0{\cdot}414\sqrt{\mu}$. With this minimum velocity the meteors will describe hyperbolic orbits round the centre of the Earth. In fact, admitting for a moment that one day before their fall they have not yet undergone any attraction from the Earth, they will then be at a distance $= 0{\cdot}414\sqrt{\mu}$ unities, and we shall have $V^2 > \frac{2g}{r}$, that is, in numbers

$$(0{\cdot}414)^2\,\mu > \frac{2\mu}{319455}\times\frac{1}{0{\cdot}414\sqrt{\mu}} \quad \text{or} \quad (0{\cdot}414)^2 > 0{\cdot}00879.$$

This inequality would be still greater if we had introduced the attraction of the Earth during the preceding days, and the hyperbolic character of the orbit would have become still more marked. Having then established it for the smallest angular velocity, we have in fact established it for all the meteors which the Earth meets during its annual revolution.

We may therefore resume the reasonings of §§ 1 and 2. Only we must in figure 1 replace the point S by the Earth, the point U by the radiant point R_1, the parabolic orbit of each molecule by a hyperbolic orbit. We may take for the plane P P′ a plane normal to the asymptotes (parallel to each other) of all the hyperbolas. Lastly, we have to consider the relative velocity V as belonging to an infinite distance, which gives for the dimensions of the orbits

$$\left.\begin{aligned} p = q\,(e+1) = a\,(e^2-1) = \frac{V^2 s^2}{g},\quad e^2 = 1+\frac{V^4 s^2}{g^2},\\ a = \frac{g}{V^2},\quad \tan M = \frac{V^2 s}{g} = \frac{s}{a},\quad \cos M = \frac{1}{e},\ \sin M = \frac{s}{ae}, \end{aligned}\right\} \quad (43)$$

where p, q, e, s, and M signify, as in §§ 1 and 2, a is the semi-axis major, and g the constant of terrestrial attraction.

The total deviation undergone, in consequence of this attraction, by a meteor which passes near the Earth will thus be $180° - 2\,M = 2\,\delta$, so that we shall have

$$\tan \delta = \cot M = \frac{g}{V^2 s}, \quad (44)$$

where δ will be larger as s is smaller.

What is then the value of δ for a meteor which grazes the surface of the Earth?

The formulæ (43) give

$$e + 1 = \frac{V^2 s^2}{g q},\quad e-1 = \frac{V^2}{g} q,\quad 2 = \frac{V^2}{g}\left(\frac{s^2}{q} - q\right), \quad (45)$$

and for $q = 1$,

$$s^2 = 1 + 2\,\frac{g}{V^2},\quad \tan \delta = \frac{g}{V^2}\left(1 + 2\,\frac{g}{V^2}\right)^{-\frac{1}{2}}. \quad (46)$$

In the numerical calculations to be based upon these formulæ, it would be necessary to pay attention to reduce g and V to the new unity which has just been introduced. In fact, instead of the radius of the terrestrial orbit, we have taken as unity of distance the radius of the Earth; we must therefore, if π be the parallax of the Sun, write

$$g = \frac{\mu}{3^{19455}}\,(\cot \pi)^3,\quad V^2 = (3 + 2\,\sqrt{2}\cos H)\,\mu \cot^2 \pi,$$

or, for $\pi = 8''{\cdot}916$,

$$\frac{g}{V^2} = \frac{0{\cdot}07241}{(3 + 2\sqrt{2})\cos H}.$$

The following are some values calculated by means of the formulæ (46) and (47):—

H.	$\frac{g}{V^2}$	s^2	δ.
°			° ′
0	0·0124	1·025	0 42
45	0·0145	1·029	0 49
90	0·0241	1·048	1 21
135	0·0724	1·145	3 52
180	0·4217	1·843	17 15

In this table δ is the perturbation undergone by the radiant point when observed at the horizon. Nearer the zenith this perturbation is less considerable, and at the zenith it is zero.

The value of s^2 indicates in what proportion the attraction of the Earth, in deviating the meteors, multiplies the number of them which fall upon the Earth.

Let us first pursue the latter inquiry, and see what is the density of the swarm at a place on the Earth situate at n' degrees of distance from the place which has the radiant point at its zenith.

Consider, again, a parallelopiped in the vicinity of the plane PP′ and of the volume $ds \times s\,d\zeta \times d\mathrm{A}$.

The formula (16) gives

$$w_1 w_2 = \sin n' . d\zeta.$$

Then differentiating the formula

$$p = 1 - e\cos(\mathrm{M} + n') = 1 - \cos n' + \sin n' \tan \mathrm{M}, \qquad (48)$$

which is the formula for the hyperbola, r being put $= 1$; and substituting the values derived from the formulæ (43),

$$dp = \frac{V^2}{g} 2\,s\,ds, \quad d.\tan \mathrm{M} = \frac{V^2}{g} ds,$$

we obtain

$$w_1 w_3 = dn' = \frac{V^2}{g} \frac{2\,s - \sin n'}{\sin n' + \cos n' \tan \mathrm{M}} ds, \qquad (49)$$

Lastly, the formula (19) for $r = 1$ gives by means of the formulæ (43) and with the relation $\mathrm{V}\,dt = d\mathrm{A}$,

$$dr = \sqrt{1 - s^2 + \frac{2g}{V^2}} . d\mathrm{A}. \qquad (50)$$

The volume of the parallelopiped at the instant of the fall will therefore be

$$w_1 w_2 \times w_1 w_3 \times dr = (2s - \sin n') \sin n' \frac{V^2}{g} \frac{\sqrt{1 - s^2 + \frac{2g}{V^2}}}{\sin n' + \cos n' \tan M} d\zeta \times ds \times dA,$$

and since, by virtue of the formulæ (48) and (43),

$$\sin n' + \cos n' \tan M = \frac{V^2 s}{g} \sqrt{1 - s^2 + \frac{2g}{V^2}}, \qquad (51)$$

we may say that the effect of the attraction of the Earth is to multiply the density of the swarm by a factor

$$f = \frac{s^2}{\sin n' (2s - \sin n')}. \qquad (52)$$

Let us apply to this case the other process of § 2, which consists in calculating in the first instance the parallelogram formed by the Nos. 1, 3, 5, and 7.

We have for the equation of the orbit expressed in rectangular co-ordinates, with the centre of the Earth as origin, and with the axes of x parallel to the asymptote,

$$x^2 + y^2 = (p + x - y \tan M)^2,$$

and differentiating with respect to y, p, and M, and then putting $r = 1$, $x = \cos n'$, $y = \sin n'$, we find

$$dy = \frac{dp - \sin n' \, d.\tan M}{\sin n' + \tan M} = \frac{V^2}{g} \frac{2s - \sin n'}{\sin n' + \tan M} ds, \qquad (53)$$

Differentiating then the same formula with respect to x and y, we have for the same values of r, x, and y,

$$\tan \alpha_1 = \frac{dy}{dx} = \frac{1 - \cos n'}{\sin n' + \tan M},$$

whence for the distance of the two orbits $\tau_1 \tau_5$ and $\tau_3 \tau_7$

$$dy \cos \alpha_1 = \frac{V^2}{g} \frac{2s - \sin n'}{\sqrt{2p + \tan^2 M}} ds = \frac{2s - \sin n'}{s \sqrt{1 + \frac{2g}{V^2}}} ds, \qquad (55)$$

To have the base $\tau_1 \tau_5$ of the parallelogram, we may remark that the primitive velocity is V, and that for the unity of distance is $\sqrt{V^2 + 2g}$; whence

$$dA = V \, dt, \quad \tau_1 \tau_5 = \sqrt{V^2 + 2g} \, . \, dt = \sqrt{1 + \frac{2g}{V^2}} \, dA, \qquad (56)$$

and applying, lastly, the known value of $w_1 w_2$ we shall have for the volume of the parallelopiped at the moment of the fall

$$\frac{1}{s}(2s - \sin n')\sin n'.\ d\zeta\ dA\ ds$$

which leads again to the formula (52).

Let us remark that this formula, for $s = 0$, and consequently $n' = 0$, gives $f = \frac{0}{0}$, an expression of which the value is easily determined. For n' indefinitely small the formula (48) gives

$$\sin n' = \frac{p}{\tan M} = s,$$

and thence

$$f = \frac{s^2}{s^2} = 1.$$

The limit of the places on the Earth which receive the rain of meteors is determined for the value of s^2 in the formula (46) for which (51) gives

$$\sin n' + \cos n' \tan M = 0,\ n' + M = 180°.$$

But from the formula (43)

$$e = \frac{V^2 + g}{g},\ \sin^2 M = \frac{V^2(V^2 + 2g)}{(V^2 + g)^2},\ s \sin M = \frac{V^2 + 2g}{V^2 + g},$$

whence for f in this limiting case

$$f = \frac{(V^2 + g)^2}{V^2(V^2 + 2g)} = 1 + \frac{g^2}{V^2(V^2 + 2g)},$$

a quantity which in general will not differ sensibly from unity.

The last meth od has a particular advantage in that it gives us in the formula (54) an expression for the angle α_1 between the

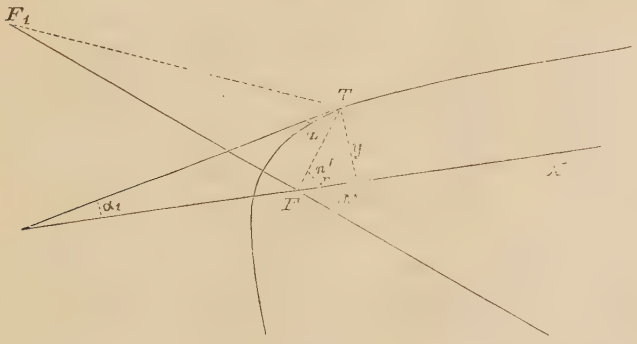


Fig. 7.

asymptote and the direction of motion at the instant of the fall (fig. 7). This angle is therefore the perturbation undergone by

the radiant point for a place on the Earth determined by the angle n'. It will be preferable to express this perturbation as a function of z, the zenith distance of the observed radiant point. Introducing for this purpose the relation $n' = z + \alpha$, the formula (54) becomes

$$\cos z \cos M = \cos (\alpha_1 + M), \qquad (57)$$

or, replacing M by δ it is

$$\cos z \sin \delta = \sin (\delta - \alpha_1), \qquad (58)$$

where the value of δ is give by the formula (44).

We may therefore calculate the perturbation α_1 as soon as we have a relation between z and s_1, a relation which is found in the following manner. Connecting, in fig. 7, the point T with the points F and F_1 we have a triangle the sides of which are 1, $2a + 1$, and $2ae$, and in which the angle opposite to the last-mentioned side is $= 2z$. We have therefore

$$\sin^2 z = \frac{a^2 (e^2 - 1)}{2a + 1} = \frac{ap}{2a + 1} = \frac{s^2}{1 + 2\frac{g}{V^2}}. \qquad (59)$$

To recapitulate we may calculate the correction α_1 of an observed z by the formula

$$s = \sin z \sqrt{1 + \frac{2g}{V^2}}, \tan \delta = \frac{g}{V^2 s}, \sin(\delta - \alpha_1) = \sin \delta \cos z, \qquad (60)$$

which will serve equally well in the case of an observed s, to calculate successively z, δ and α_1.

For $z = 0$ the formula (60) gives $\alpha_1 = 0$; for $z = 90°$ we have first the formulæ (46) and then $\alpha_1 = \delta$.

The following table gives some values of α_1, for the case $H = 180°$, that is, $\frac{g}{V^2} = 0{\cdot}3809$.

z	s	δ	$\delta - \alpha_1$	α_1
°		° ′	° ′	° ′
0	0·0000	90 0	90 0	0 0
15	0·3514	50 12	47 54	2 18
30	0·6788	31 15	27 12	4 39
45	0·9600	23 43	16 32	7 11
60	1·176	19 44	9 43	10 1
75	1·311	17 50	4 33	13 17
90	1·358	17 15	0 0	17 15

I have added a table of some values of f, on the same supposition as to the value of H, calculated by the formulæ

$$a = \frac{g}{V^2}, \tan M = \frac{s}{a}, p = \frac{s^2}{a}, \cos (M + n') = (1 - p) \cos M,$$

$$f = \frac{s^2}{\sin n' (2s - \sin n')}.$$

z	s	M	$M+n'$	f
°		° ′	° ′	
0	0·0000	0 0	0 0	1·00
15	0·3514	39 48	57 6	1·02
30	0·6788	58 9	92 46	1·03
45	0·6900	66 17	118 29	1·03
20	1·176	70 17	140 13	1·04
75	1·311	72 10	160 25	1·06
90	1·358	72 45	180 0	1·10

§ 5. The preceding paragraphs give the principal features which characterise the phenomenon of a meteoric shower continuing during a year.

In § 3 we have seen how necessary it is to take account of the annual variations presented by the radiant point. Probably it is a less exact proceeding to consider these points as constant during a fortnight or even during two months, as is done in Mr. Greg's chart.

The general formulæ of this paragraph allow us to decide two questions relating to the theory of falling stars.

In the first place, we may ask if the cometary systems contain members of an inferior density, which resolve themselves in our neighbourhood, so as to form there currents of isolated particles. The points of the sphere I. to VII., which I have noticed in vol. xxvii. of the *Monthly Notices*, may be identified in this investigation with the point U of paragraphs 1 and 2.

This calculation has already been made, as an example of the application of the formulæ (41) for the point IV., which is one of those best determined. In comparing the results to the chart, in which Mr. Greg has put a total of 56 radiant points, I find that there are two of these points which may perhaps have the same origin as the Comets of 1857 and 1867.

There is first, point 27, indicated in the following manner:—

May 29 to June 17 $\alpha = 336°$, $\delta = 45°$,
from whence follows $\lambda = 2°$, $\beta = 49°$,

whilst the table given at the end of § 3 indicates for the same interval points R_1 varying between the limits

$\lambda = 8°$, $\beta = 45°$,
and $\lambda = 39°$, $\beta = 50°$,

and we have, moreover, the point 48,

Oct. 18 to Nov. 3 $\alpha = 83°$, $\delta = 12°$,
$\lambda = 83°$, $\beta = -11°$,

whilst the before-mentioned table gives for the same interval points R situated between

$$\lambda = 76°, \quad \beta = -20°,$$
$$\lambda = 88°, \quad \beta = -20°.$$

Certainly I am far from considering this first approximation as a decisive proof, but there is one circumstance which perhaps gives it a little more importance. This is that on November 4th, the Earth, as seen from the Sun, has a longitude of 43°, which is the mean longitude of the ascending nodes of the before-mentioned comets; on May 29th, on the contrary, it had a longitude of 248°, which is nearly the direction of the descending node of the Comet 1867, III.

If, then, the coincidence found is more than mere chance, we should say that in November we ought to meet meteors coming direct from Space; in June, meteors which have already passed their perihelion; but all having the same origin as the cometary system of 1857–1867. But this is a point which requires further investigation.

In the second place, it is an important question if, among the radiant points actually known, there are any which belong originally to the same swarm. To answer this, we may calculate the geometric locus upon the sphere of all the radiant points belonging to the same swarm, to the point U of which we give successively the latitudes 0°, 10°, 20°, 90°. We may represent each of these curves in a map, having the pole of the ecliptic for its centre. Then giving to the curve a rotatory motion about this centre, we would easily recognise, in comparing it with the known radiant points, which of these points may have had a common origin.

I propose to apply the formulæ to these two points of investigation.

In § 4 the necessity of taking account of the Earth's attraction becomes apparent. In the most disadvantageous case the apparent radiant point may have sustained a perturbation of more than 17°. This perturbation, although having an origin entirely different, has much resemblance to the atmospheric refraction. It diminishes the zenith distance, and so much the more as this co-ordinate is larger. In future it will be necessary then to note the hour and the minute of each observation made upon a falling star.

It would be unjust not to mention here that M. Schiaparelli has just published an elaborate Memoir entitled *Note e Riflessioni intorno alla Teoria Astronomica delle Stelle cadenti*, a memoir in which he has devoted an ample discussion to the effects of the terrestrial attraction upon the trajectories of meteors. When I received the copy which the illustrious Italian astronomer has done me the honour of sending me, the greater part of my calculation had been already made. I therefore publish them, at the same time acknowledging the priority of the publication by M. Schiaparelli of some results which appear also in the present Memoir.

Utrecht, January 1868.

Additional Identifications of Double Stars in the Synoptic Catalogues of Sir William Herschel's Micrometrical Measurements &c., with a List of Errata. By Sir J. F. W. Herschel, Bart.

Having been engaged since the communication to this Society of my Synoptic Catalogue of my Father's Double Stars, in entering up the measures therein recorded in their places in a general digest of all the recorded measures of all known double stars (a task begun long ago, and which, though I can never look forward to complete, I hope to leave in such a state of forwardness as will perhaps ensure its completion by some other hand), I have been led by the coincidence, or near coincidence, of the measures with those of stars observed by others, taken in conjunction with so near an approximation of place (when reduced to a common epoch) as to make it matter of reasonable probability that the same object has been brought into the field of view in both telescopes, to the identification, more or less probable, of a considerable number of these stars with those subsequently measured. Under the impression that information of this kind cannot but prove interesting to observers engaged in such measurements, and as supplementing the identifications of a similar kind already embodied in the Memoir above mentioned, I here subjoin a list of the objects in question. Among them occur some few whose places could be assigned only by loose approximation from my Father's allineations, but which now can be stated with precision: by which some trouble will be saved to an observer who might otherwise be disappointed by finding it necessary to sweep for some distance round the assigned place of an object before getting it into his field of view.

In the progress of this work I have been led to the detection of a somewhat formidable list of Errata in the printed Catalogue, which I consider it a duty to communicate, apologising, as best I may, for their occurrence, and making the only amends in my power by pointing them out for correction.

Subsequent additional Identifications more or less probable of Double Stars in the Synoptic Catalogues with each other or with objects observed by other Astronomers.

H. I. 11 is also Wr. 136
I. 13 = Σ. 2545*= S. 790
I. 14 *is* 23 *Aquilæ*, as suggested in col. 12 (nisi)
I. 56 = Σ. 178 = P. i. 191
H. I. 63 = S. 778
II. 63 = S. 553
II. 66 = S. 764
II. 70 = S. 734
II. 86 = Σ. 2016

* I. 13 was assumed as identical with Σ. 2541 on the authority of Struve himself. Mr. Dawes, however, has shown that it is really Σ. 2545: a circumstance which had escaped my recollection; but which is proved to be the fact by the agreement of the measures and the existence of a small companion.

H. II. 97 = S. 775
III. 17 = Sh. 341
III. 37 = Σ. 437??
III. 38 = Σ. 439??
III. 46 = III. 114?
III. 71 = S. 795
III. 77 = S. 426
III. 80 = S. 412
III. 108 = Sh. 217 *vice* III. 109??
III. 114 = III. 46?
IV. 23 = S. 756?
IV. 45 = Sh. 57
IV. 71 = Sh. 324
IV. 92 = S. 759
IV. 127 = Σ. 2434
V. 72 = Sh. 234
H. V. 80 = S. 817
V. 119 = Σ. 734, hardly a doubt.
V. 136 = S. 735
VI. 41 is miscalled by Sh. iv. 41
VI. 87 is miscalled by Sh. vi. 41
H.N. 10 = S. 753
H.N. 11 = Sh. 352
H.N. 13 = Sh. 303
H.N. 33 = Sh. 206
H.N. 36 = Σ. 1466
H.N. 61 = Σ. 1065
H.N. 91 = Σ. 3030?
H.N. 105 = Σ. 224??
H.N. 109 = Sh. 300
H.N. 115 = S. 660 "nova"
H.N. 142 = *Leonis* 339

These identifications, supposing those marked as more or less doubtful (? or ??) verified by future telescopic examinations, will authorize the following more exact places of the stars here numbered in place of those in the Synoptic Catalogue in order of R.A. viz.:—

General No.	Name of Star.	W.H.'s Class and No.	R.A. 1880·0. h m s	Prec. in R.A.	N.P.D. 1880·0 ° ′ ″	Prec. in N.P.D.	Authority.
41	Ceti	I. 56	1 45 40·0	+ 3·18	79 46 56	− 17·9	Σ.P.M.
55	Arietis	IV. 105	2 4 21·7	3·22	76 52 46	− 17·1	Σ.P.M.
97	Persei	III. 37	3 36·5	3·74	58 18	− 11·8	Σ.
98	Persei	III. 38	3 37 2·8	3·74	58 14 0	− 11·8	Σ.P.M.
182	Orionis	V. 119	5 27 3·6	3·03	91 48 7	− 2·8	Σ.P.M.
243 } 245 }	Monocerot.	{ III. 46 III. 114 }	6 35·6	3·30	80 7·0	+ 3·1	(B.A.C.)
499	Serpentis	II. 86	16 6 28·2	2·81	77 46 43	+ 9·6	Σ.P.M.
609	23 Aquilæ	I. 14	19 12 26·1	3·07	89 7 57	− 6·3	B.A.C.
624	Aquilæ	I. 13	19 32 8·1	3·30	100 25 36	− 7·7	Σ.P.M.
805	Piscium	N. 91	23 34 33·5	+ 3·07	91 2 52	− 19·9	Σ.P.M.

Errata in the Synoptic Catalogue.

Page
25. No. 409, *cols.* 6, 7, *for* 3 31·1 | 70 48 | *read* 3 21 ± | 79 15 ± |
78. *In the heading of col.* 1, *for* Class IV., *read* Class V.
90. *In the heading of col.* 1, *for* Class IV., *read* Class VI.

(*In the Synoptic Catalogue by Classes and Numbers.*)

Class. No.
I. 3 *in col.* 6, *for* 348·60, *read* 11·40.
I. 13 ,, 12, *insert* Triple. A C = 7 or 8″.

Class. No.

I. 60 *in col.* 12, *for* 118°, *read* 5°.
I. 70 ,, 12, *for* Wr. 90, *read* Wr. 99.
I. 72 ,, 12, *for* S. 133, *read* Sh. 133.
I. 87 ,, 5, *before* ·381, *insert* 1802.
I. 96 ,, 6, *for* 320·05, *read* 326·05.
II. 11 ,, 3, *for* Nov. 19, 1781, *read* Oct. 7, 1779.
II. 13 ,, 10, *after* 1780·537, *insert* 4·02 ?
II. 21 ,, 12, *for* Σ. 1199, *read* Σ. 1999.
II. 91 ,, 3, *for* Sagittarii, *read* Sagittæ.
II. 91 ,, 12, *after* P. xix. 322 *insert*, erroneously so called by Struve.
III. 2 ,, 4, *for* 1782·753, *read* 1802·753.
III. 7 ,, 12, *for* Sh. 215, *read* Sh. 217.
III. 13 ,, 1, 2, 12, *for* 5 29·0, *read* 5 29·4; *after* Orionis *insert* 133, *and for* Σ. 745, *read* Σ. 747.
III. 14 ,, 1, 2, 12, *for* 5 29·4, *read* 5 29·0; *after* Orionis *dele* 133, *and for* Σ. 747. *read* Σ. 745.
III. 19 ,, 6, *for* 182·73, *read* 181·44.
III. 49 ,, 10, *for* 17·50, *read* 12·50.
III. 50 ,, 6, *for* 340·17, *read* 341·17.
III. 51 ,, 10, *after* 1783·003, *insert* 14·69.
III. 55 ,, 9, *for* 1783·81, *read* 1783·181.
III. 103 ,, 10, 11, *insert in the blank spaces respectively* 12·47 *and* 2.
III. 110 ,, 8, *for the lower* A B, *read* A C.
IV. 15 ,, 12, *for* Σ. 1674, *read* Σ. 1694.
IV. 22 ,, 12, *for* Σ.C.P. 706 = 63 Cygni ? *read* Σ. 2743.
IV. 24 ,, 6, *for* 45·68, *read* 314·32.
IV. 77 ,, 12, *dele* Sh. 73
IV. 85 ,, 4 *for the lower* A B, *read* A D.
IV. 132 ,, 12, *dele* H N. 62.
V. 89 ,, 8, *for* A C, *read* A B.
V. 97 ,, 12, *for* V. 121, *read* VI. 121.
V. 99 ,, 12, *for* Σ.C.P. 749, *read* Σ. 2900.
V. 121 ,, 12, *dele* For two more probable measures of distance, see V. 97.
V. 122 ,, 12, *for* Sh. 119, *read* Sh. 189.
V. 131 ,, 12, *for* Σ. 476, *read* Σ.C.P. 476.
VI. 121 ,, 12, *insert*, For two more probable measures of distance, see V. 97.
H N. 38 ,, 2, *for* 15 35·0, *read* 12 35·0.

(*In the Catalogue in order of R.A.*)

Star Nos.

75, 76, *col.* 2, *transfer the letter n from* Arietis *to* Persei.
186, 189, ,, 2, *after* Orionis *transfer* 133 *from* No. 186 *to* No. 189.
199, ,, 2, *for* 23 Leporis, *read* 13 Leporis.
272, ,, 2, *after* Canis Minoris, *insert* 31.
322, ,, 4, *for* 8 7·1, *read* 8 8·4.
738, ,, *Note* † *for* 41 23·2, *read* 48 49·2.
795, ,, *col.* 6, *for* 19 4·1, *read* 99 4·1.
801, ,, *cols.* 4, 6, 8, *for* 24 45·5, *read* 24·8; *for* 32 6 45, *read* 32 6·8; *and for* B.A.C. *read* (B.A.C.).

Lastly, at the end of the Catalogue add.

Omitted Stars.

No.			h m s	s	° ′ ″	″	
435 *bis*	Bootis	V. 98	14 7 24·0	+ 3·00	84 2 13	+ 17·1	Σ.P.M.
742 *bis*	79 Cygni	VI. 57	21 38 27·8	+ 2·47	52 15 56	− 16·3	B.A.C.
813	Cassiopeæ	V. 79	24 ±	..	unidentifiable	..	..

Collingwood, Feb. 22, 1868.

On the Planetary Nebula 45 H IV. *Geminorum.*

By H. C. Key, Esq.

During the last three years I have constantly observed this remarkable object whenever a favourable opportunity occurred, but until the last few months without any special result. My instrument during that period had been only sufficient to show the star as nebulous, an intervening darker space round the nucleus, and a faint luminous ring at some distance. Since that time my optical means have been considerably increased, and a careful scrutiny has brought to light an additional feature, which seems to have escaped the notice of former observers, and of sufficient interest to induce me to lay it before the Society.

Smyth tells us (*Cycle*, vol. ii. p. 176) that in 1787 Sir William Herschel observed this object, and described it as "a star of the 9th magnitude, with a pretty bright nebulosity, equally dispersed all around;" and he calls it "a very remarkable phenomenon." And that Sir John Herschel describes it as "a star of the 8th magnitude, exactly in the centre of an exactly round bright hemisphere 25″ in diameter."

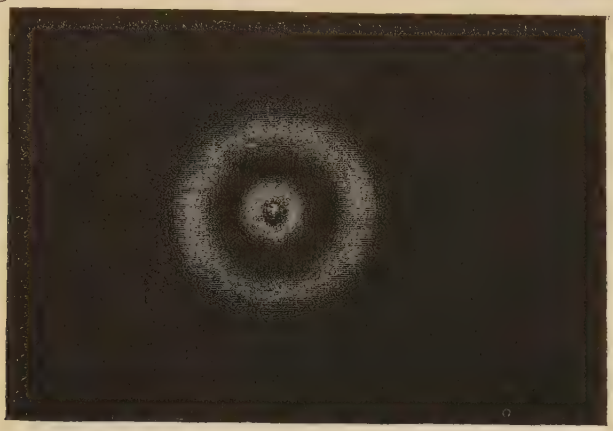
From the Earl of Rosse's account of this object in the *Philosophical Transactions*, 1850, of which Mr. Knott has kindly forwarded me an abstract and rough drawing, it appears that he saw it as a nebulous star with a black patch close to it on the preceding side, a less luminous space, somewhat unequal in breadth, surrounding the nucleus, and a luminous ring at some distance; this ring being of less breadth on the following side.

Mr. Lassell's drawing of this object in 1862 (*Mem. R. A. S.* vol. xxxvi.) represents a star in the centre of a planetary disk, surrounded by a non-luminous space; and, at some distance, by a luminous ring of considerable breadth. He also says, "I can see no trace of the dark patch in Lord Rosse's drawing near the bright centre."

The present appearance of this object, as seen in my instrument, is that of a bright, but somewhat nebulous star closely surrounded by a dark ring; this again by a luminous ring; then

an interval much less luminous, and, finally, at some distance, an exterior luminous ring.

The accompanying drawing (which has been repeatedly verified and corrected), although an inadequate one, if held at such a distance from the eye that the interior bright ring is just seen



45 H IV. Gem. 18-inch Reflector, power 510.

distinctly detached from the central star, gives a tolerably fair representation of this remarkable object as it appears in my instrument.

The whole is almost exactly symmetrical, although not quite so; the dark space between the two bright rings being darker on the north following side, and the preceding side of the whole object is rather fainter than the rest. Of the two luminous rings the interior is considerably the brightest. Like the annular nebula in *Lyra*, this object bears magnifying wonderfully well: with 150 little more is to be seen than a star in the centre of an extensive gauzelike, nebulous disk; with 300 I detected the interior ring; and 510 I found the most suitable power in every respect; with 666 I did not seem to gain any advantage, but rather the contrary. I may add that I have failed to see anything of the black patch in the Earl of Rosse's drawing, as well as the star shown by Mr. Lassell near the edge of the nebula.

On considering these several observations, which extend over a period of 81 years, from 1787 down to the present time, we can hardly fail to be struck by the progressive character of the results, which seems to be independent of the optical means employed. To both Sir William and Sir John Herschel there appeared merely a uniform nebulous planetary disk surrounding the central star, without any indication of a ring. To the Earl of Rosse, with his enormous optical power, there was visible only one exterior ring, and a small circular dark space near the central star, preceding it. To Mr. Lassell, with scarcely inferior power (comparatively), there was no appearance of an interior

luminous ring. While, in my own instrument, which, although somewhat more powerful than the 20-foot reflectors (front view) of the Herschels, is of incomparably inferior power to the instruments of the Earl of Rosse and Mr. Lassell, the interior bright ring was visible at once during the first night's observation, and with a power of 510 is quite obvious.

Not to draw any very definite conclusions from these results, one fact, at all events, seems abundantly evident,—viz., that whereas at the date of the Herschels' observations there was no appearance whatever of a ring surrounding the central star, at the present time there are two.

The instrument with which my observations were made consists of a silvered glass speculum of 18 inches aperture and 10 feet focal length, of my own making, mounted as a Newtonian equatorially.

I estimated the extreme diameter of the whole object at 35″; and the diameter of the inner ring, taken at its brightest part, at 9″; while its inner diameter I judged to be about 5″.

Stretton Rectory, Hereford,
February 26, 1868.

Postscript, March 23.—Since writing the above I have seen a dark patch situated in the inner dark ring close to the central star. It is a very faint object in my instrument, but I can speak with certainty of its existence; the estimated angle of position is about 5°. I am not aware of the position of the dark patch seen by the Earl of Rosse.

Note on the Occultation of α Tauri on May 22, 1868.

(*Communicated by R. S. Newall, Esq.*)

It may perhaps be desirable to call the attention of observers to the occultation of *α Tauri* on May 22, 1868, because it is not mentioned in the *Nautical Almanack* and other ephemerides on account of its occurring near the time of New Moon. As the star will be about 8° distant from the Sun, there seems little reason to doubt that, in a clear sky, and with a good Equatoreal, the occultation may be observed very well, provided the necessary precautions are not neglected. At any rate, the observation will be worth trying, be it merely as a matter of curiosity, since a similar favourable opportunity of observing an occultation of *α Tauri* so near the Sun will not offer itself again before the year 1885 or 1886.

The elements for computing the occultation beforehand, according to Bessel's formulæ (which may be found in the *Berliner Jahrbuch* and in the *Connaissance des Temps*), are these:—

For Greenwich, Paris, and neighbourhood.	For Washington and neighbourhood.
T = May 22 $6^h\ 50^m{\cdot}0$ Greenwich M.T.	T = $5^h\ 50^m{\cdot}0$ Greenwich M.T.
$h = 96°\ 5'{\cdot}2$	$h = 81°\ 2'{\cdot}7$
$p = +\ 0{\cdot}6394$	$p = +\ 0{\cdot}0464$
$q = +\ 0{\cdot}6320$	$q = +\ 0{\cdot}5316$

$$p' = + 0\cdot5930$$
$$q' = + 0\cdot1003$$

The following list contains the local mean times of disappearance and reappearance for a few observations and also the corresponding angles of position Q of the star at the apparent centre of the Moon.

	Disappearance, Local M.T. h m	Q	Reappearance, Local M.T. h m	Q
Berlin	7 20·9	41·3	7 57·4	308·4
Bonn	6 56·0	51·8	7 39·3	298·3
Cambridge, England	6 26·1	53·0	7 11·5	296·6
Cambridge, Mass.	0 37·5	100·4	1 50·6	234·1
Greenwich	6 26·1	55·1	7 12·6	294·6
Liverpool	6 12·3	51·8	6 57·9	297·4
Oxford	6 20·7	55·3	7 7·5	294·4
Paris	6 37·4	60·9	7 25·6	289·4
Washington	0 3·1	108·7	1 12·1	223·5

It need scarcely be mentioned that, in order not to miss the reappearance, the place of emergence will have to be determined with some care. Bessel's expedient, of placing a wire in the direction $Q \pm 90°$, and finding the part of the Moon's limb at which it is a tangent, will perhaps give little trouble at the European observatories, as the reappearance takes place near the middle of the illuminated crescent, where its breadth will be nearly 10″. At the American observatories, where the star reappears near the thin horns of the crescent, the difficulty will be somewhat greater. The direction and distance of the Sun's centre with respect to the star are:

G.M.T.	Angle of Position.	Distance.
6^h	302° 52′·3	8° 10′·9
8	303 15·1	8 7·3

Observations of Planets (94), (95), (96), *and* (97). By Dr. R. Luther.

(94), discovered by Mr. Watson at Ann Arbor. 11.12 magnitude.

	Bilk M.T. h m s	R.A. h m s	Decl. ° ′ ″	
1867, Oct. 25	8 56 16·4	0 20 39·70	+4 35 46·8	13 comp.
26	8 30 49·8	0 20 3·49	+4 34 9·3	10 ,,
28	9 9 24·5	0 18 51·67	+4 30 55·9	9 ,,

(96), discovered by myself at Bilk, Düsseldorf. 10.11 magnitude.

	Bilk M.T.	R.A.	Decl.	
	h m s	h m s	° ′ ″	
1867, Nov. 23	9 48 15·7	4 1 32·00	+21 30 17·1	11 comp.
23	11 11 1·6	4 1 28·81	+21 29 53·0	10 ,,
29	8 59 20·0	3 56 24·29	+20 44 47·3	2 ,,
Dec. 3	10 28 32·7	3 53 4·23	+20 13 59·4	12 ,,

The name *Arethusa* was kindly given by Professor Galle and Dr. Günther at Breslau.

⑯, discovered by M. Coggia at Longchamp, Marseilles. 11 magnitude.

	Bilk M.T.	R.A.	Decl.	
	h m s	h m s	° ′ ″	
1868, Feb. 28	9 42 35·4	9 23 40·85	+13 29 48·2	8 comp.
	Hourly Motion	-2^s in R.A.,	$-5''$ in Decl.	

⑰, discovered by M. Tempel at Marseilles. 10.11 magnitude.

	Bilk M.T.	A.R.	Decl.	
	h m s	h m s	° ′ ″	
1868, Feb. 28	12 37 20·3	11 44 24·26	+4 41 52·5	8 comp.
	Hourly Motion	-2^s in R.A.	$+25''$ in Decl.	

⑰ is surely different from ⑨① *Ægina*.

In the month of January 1868 I have found the following corrections of the Berlin Ephemerides:—

	R.A.	Decl.
	s	′
Parthenope	+3·8	+0·1
Hebe	−0·1	+0·2
Julia	−5·1	+0·2
Ausonia	+0·2	−0·0

Bilk, Düsseldorf, 1868, *March* 4.

Ephemeris of Brorsen's Comet. By Dr. C. Bruhns, Director of the Observatory of Leipzig.

I found with the perturbations of *Jupiter* the following systems of elements from the appearances of 1846 and 1857.

	1846.		1857.		1868.	
T	Feb. 25·406 Berl. T.		Mar. 29·2829 Berl. T.		Apr. 18·4835 Berl. T.	
ϖ	126 28 17·1	Mean	115 45 54·3	Mean	116 2 3·1	Mean
Ω	102 41 41·3	Equin.	101 47 27·9	Equin.	101 14 5·5	Equin.
i	30 55 16·9	1846·0.	29 48 45·2	1857·0.	29 22 38·5	1870·0.
φ	52 28 23·7		53 17 28·2		53 54 35·6	
M	637″·151		640″·732		647″·0618	

With the latter Elements we obtain for the present appearance the following Ephemeris :—

1868. 0h Berlin T.	α App. h m s	δ App. ° ′	Log. Δ	Log. γ
Mar. 10	1 7 53	− 8 8·5	0·23966	9·97841
11	10 58	7 34·0		
12	14 5	6 58·8		
13	17 14	6 23·0		
14	20 24	5 46·6	0·22708	9·95383
15	23 37	5 9·6		
16	26 52	4 31·9		
17	30 9	3 53·6		
18	33 28	3 14·6	0·21382	9·92837
19	36 50	2 34·9		
20	40 14	1 54·6		
21	43 40	1 13·6		
22	47 9	− 0 31·9	0·19985	9·90233
23	50 40	+ 0 10·5		
24	54 13	0 53·7		
25	57 49	1 37·7		
26	2 1 27	2 22·3	0·18515	9·87614
27	5 8	3 7·7		
28	8 52	3 53·8		
29	12 38	4 40·7		
30	16 27	5 28·4	0·16967	9·85050
31	20 19	6 16·9		
Apr. 1	24 13	7 6·0		
2	28 10	7 56·0		
3	32 9	8 46·7	0·15340	9·82648
4	36 12	9 38·2		
5	40 18	10 30·4		
6	44 27	11 23·3		
7	48 39	12 16·9	0·13635	9·80544
8	52 54	13 11·2		
9	57 12	14 6·2		
10	3 1 33	15 1·9		
11	5 58	15 58·2	0·11853	9·78899
12	10 26	16 55·0		
13	14 58	17 52·4		
14	19 33	18 50·3		
15	24 11	19 48·6	0·10006	9·77875
16	28 53	20 47·3		
17	33 41	21 46·5		
18	38 32	22 46·0		
19	43 27	+ 23 45·6	0·08113	9·77587

1868. 0h Berlin T.	α App. h m s	δ App. ° ′	Log. Δ	Log. γ
Apr. 20	3 48 27	+ 24 45·5		
21	53 32	24 45·5		
22	58 42	26 45·6		
23	4 3 58	27 45·6	0·06207	9·78072
24	9 20	28 45·6		
25	14 50	29 45·4		
26	20 26	30 44·9		
27	26 7	31 44·0	0·04336	9·79271
28	31 56	32 43·0		
29	37 54	33 41·3		
30	44 0	34 39·1		
May 1	50 16	35 36·2	0·02546	9·81050
2	56 41	36 32·5		
3	5 3 16	37 27·8		
4	10 2	38 22·1		
5	16 59	39 15·4	0·00895	9·83246
6	24 7	40 7·4		
7	31 27	40 58·1		
8	39 0	41 47·3		
9	46 46	42 34·8	9·99440	9·85701
10	54 45	43 20·5		
11	6 2 57	44 4·3		
12	11 23	44 46·0		
13	20 1	45 25·4	9·98229	9·88287
14	28 53	46 2·4		
15	37 59	46 36·9		
16	47 16	47 8·8		
17	56 45	47 37·8	9·97313	9·90909
18	7 6 26	48 3·8		
19	16 16	48 26·6		
20	26 14	48 46·3		
21	36 19	49 2·8	9·96724	9·93502
22	46 30	49 15·8		
23	56 46	49 25·3		
24	8 7 4	49 31·4		
25	17 22	49 34·1	9·96488	9·96027
26	27 38	49 33·4		
27	37 52	49 29·3		
28	48 2	49 21·7		
29	58 6	+ 49 10·7	9·96615	9·98460

14 *March*, 1868.

*Description of a Zenith Telescope.** By J. Simms, Esq.

I have been requested by several members of the Society to describe this Zenith Telescope, with the view of bringing forward a method of determining the latitude which has been for several years generally adopted by the United States Coast Survey, and which not only has the advantage of being simple, but also when the places of the stars made use of have been well ascertained, is extremely accurate.

The instrument is supported upon a strong tripod having feet screws for levelling; to this tripod is fixed the azimuth circle and also the fixed vertical axis. A hollow axis which serves to support the upper part of the instrument, moves upon the fixed axis. The upper part consists of a telescope, fixed to the end of a horizontal moveable axis, so that, in fact, the movements are those of an altazimuth. An extremely sensitive level is fixed to the telescope which also carries a micrometer with a screw of long range. There is a peculiarity in this instrument in the manner of bringing the weight of the upper part over the centre of the upright pillar, which deserves notice. In order to accomplish this, and at the same time to avoid the flexure which would be caused by the overhanging position of the telescope, a steel lever having its fulcrum over the centre of the instrument is, by a bend, passed round to the front of the telescope, where it supports a small pivot which is really a continuation of the horizontal axis, the other end of the lever carries a counterpoise.

The Zenith Telescope in its present form was arranged by Würdermann of Washington, U.S.

In Pearson's *Astronomy* may be seen represented two varieties of Zenith Telescope, one of which has the level and micrometer of Würdermann's instrument, whilst the other possesses the horizontal axis, it would thus appear that the modern form is a combination of two previously existing models.

The method of observation is known as Talcott's, it is described in the U. S. Coast Survey Report for 1857.

Two stars are selected, one of which passes the meridian to the north, and the other at nearly the same distance to the south of the zenith. The telescope is brought into the plane of the meridian and set for the star which first passes the meridian; when visible it is bisected by the micrometer wire, the tangent screw of the instrument being used. The telescope is then turned 180° in azimuth, and when the second star makes its appearance, should there be any difference in the zenith distances, this difference is measured by the micrometer screw.

It is evident that, having the sum of the zenith distances as given by the Catalogue, and having obtained the difference by means of the instrument, the latitude may be readily deduced therefrom.

* Exhibited at the Meeting. Ed.

Should the position of the level vary between the two observations, a correction will have to be applied; refraction may, in general, be neglected, as the difference in the refraction of the two stars (in most cases a very small quantity) is that which alone has to be regarded.

From a paper by the late Mr. Pond, Astronomer Royal, read before the Royal Society, March 13, 1834, entitled "Some Suggestions relative to the best method of employing the New Zenith Telescope lately erected at the Royal Observatory," it would appear that he suggested and made use of this mode of observing: this paper appears to have been generally lost sight of.

The Great Nebula in Orion. By Father A. Secchi.

I take the liberty of presenting to the Royal Astronomical Society a drawing of the great Nebula of *Orion*, which was commenced several years ago, and finished last year by combined observations made by myself and Padre Ferrari, my assistant. Last autumn some copies of it were distributed to friends, but not as definite specimens. Lately I have re-examined this object and found the figuring correct, as seen on dark nights in our 9-inch refractor. But upon observing it in moonlight, I was surprised at the amount of details which then came out. I resolved, therefore, to take advantage of this circumstance, and to introduce these details into the drawing, making the observations in different phases of the Moon to obtain a more distinct graduation of light.

The present drawing embraces these results, which will, I hope, prove interesting. It may appear extraordinary that we should see such an object better in moonlight, but this is not very surprising, since it is only a consequence of that optical principle, that the difference of two lights is more easily appreciated when they are weak than when they are both very strong. This, therefore, is a case like that of the spots on *Venus*, which are better seen in daylight than at night, and of the bands of *Jupiter*, which are better seen in twilight than in complete darkness. I, consequently, hope that this drawing will not be useless, even after the great work of Lord Rosse; and it will at least show how much may be seen with an instrument of comparatively limited power, and that some information may thus be obtained respecting the influence caused by the aperture, and the amount of light of the instrument.

As I have not yet received the *Philosophical Transactions* I have not been able to compare my results with those of Lord Rosse. I saw his lordship's drawing at Sir John Herschel's last October, and I then found that the principal masses in my drawing agreed with it; I therefore hope that these minor details may in like manner agree.

As regards the spectrum of the Nebula, I have nothing to add, except that I have made an experiment which may explain why we see only one of the three hydrogen lines in the Nebula. Having obtained by a Geissler tube a good spectrum of pure hydrogen with the three characteristic lines, I found that, by diminishing the light by reflexion on a glass plate, the two lateral ones disappeared, the middle line only remaining, which is that visible in the Nebula. The simple diminution of the light may therefore account for the other two lines of this gas not being visible. I think, therefore, that it would be of great interest to have this Nebula observed in Southern regions with a larger instrument in order to ascertain, if possible, whether the other two lines can thus be rendered visible.

Extract of a letter from Father Secchi to Admiral Manners:—

"*Rome, March* 27, 1868.

"I am busy about the spectrum analysis of stars, and you will see in the *Comptes Rendus* a very advantageous method of determining the motion of the stars in space by the spectrometer. I, however, require a larger instrument, because a 9-inch object-glass is rather too small for this purpose. I have greatly improved the direct view spectroscope, so that it has become a very suitable instrument. I have introduced an eye-piece, made completely with cylindrical lenses, which is exceedingly powerful, and leaves a great deal of light. I have examined almost the whole of the Red Stars in the Catalogue of M. Schellerup, and have arrived at some very interesting conclusions. All these red stars have spectra, either furnished with bands and striæ like *α Orionis*, or like the star *Lalande* 12561, figured in my second map of the Memoir, which I have sent to the Society. As soon as the full review is finished, I will send the complete Catalogue to the Society, with figures and description.

"I have since studied the spectrum of *α Orionis* more accurately, and it seems to me that the hydrogen lines exist even in it. I have got a very good spectroscope, with a double prism, by Hoffman, and some wonderful prisms by M. Merz: with one of these I can see as many lines in the solar spectrum, as Bunsen saw with his four prisms.

"I have made a *resumé* of all the measures of double stars taken since my last publication in 1859, and in number they amount to 158 objects, the greater part of them periodical, and many of them have changed their position since my last measures, and those of Struve."

The Rev. W. R. Dawes, died February 15, at Haddenham, aged 68 years.

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